KS-8 WELL TEST PROGRAM

1 INTRODUCTION

The KS-8 well test is designed to determine the flow characteristics of production well KS-8. Major components for the power plant and the gathering and disposal system including injection well KS-3 will also be tested as part of this program. The well test program described in this document consists of the following elements:

* KS-8 well test program procedures, equipment, and instrumentation.
* H_2S abatement program to be used during the well test.
* Chemical sampling program for the analysis of geothermal brine, steam, and non-condensible gases including toxic elements.
* Chemical sampling program for the analysis of aerosols emitted from the steam rock muffler.
* Test program for power plant components using steam from KS-8 during the flow test.
* Program for injecting geothermal brine from the main separator into injection well KS-3.

Vertical venting for initial well cleanout will not be used in the KS-8 well test. Instead, the initial water-rich flow from the well will be vented through an atmospheric separator/muffler. H_2S will be abated in the steam fraction throughout the test including the initial cleanout period.

2 KS-8 WELL TEST PROGRAM

2.1 Well Test Objectives

2.1.1 Determine downhole static pressure and temperature conditions.

2.1.2 Develop wellhead production characteristics (flowrate and enthalpy verses wellhead pressure).

2.1.3 Determine production fluid chemistry.

2.1.4 Define flow and power potential of the well at the power plant system design conditions.

2.2 Test Program Description

2.2.1 Install test facility as shown in Figures 2-1 and 2-2. The production capacity of KS-8 is expected to be considerably larger than that of the previous wells drilled at Puna. For this reason, the test will employ the permanent power plant separator facilities installed on Well Pad A. These facilities can accommodate the full power plant flowrate and are therefore more suited to testing KS-8 than the small capacity test unit that was employed for testing KS-3.

2.2.2 Run static pressure and temperature survey in KS-8.

2.2.3 Open KS-8 and flow through the atmospheric flash tank\muffler for not more than four hours.

2.2.4 Divert KS-8 production to separator on Well Pad A and test for up to ten days. Collect fluid samples, obtain wellhead and downhole productivities and monitor pressure recovery after shut-in.

2.2.5 Test injectivity of KS-3 as described in Section 7.

2.2.6 Run static pressure and temperature surveys in KS-8 1, 2, 4 and 10 days after shut-in.

2.3 Test Facilities (Figures 2-1, 2-2)

The test facilities consist of a temporary 10 inch diameter flowline connected to the permanent 14 inch diameter line which delivers the total well discharge from Well Pad D to two power plant separators located on Well Pad A. Primary flow control and throttling will be accomplished with a ten inch diameter valve located on the wellhead just downstream of the two master valves.

Both separators will be in service during the test. One will be used to separate the total steam-water flow produced by the well at a pressure of 210 psi (high pressure separator). The liquid phase from this separation will be flashed down to 20 psi and separated in the second (low pressure) separator.

The steam phases from the two separators will pass through throttling valves and discharge to the atmosphere through a below ground rock muffler. The discharge line to the rock muffler will incorporate an H_2S abatement system described in Section 3. The remaining liquid from the low pressure flash will be discharged without treatment to a separate in-ground rock muffler. The low pressure separation will liberate any H_2S still entrained in the liquid and transfer the H_2S along with the low pressure steam fraction to the main steam line for abatement.

The facility will also include the provision for routing the separated brine from the high pressure separator to KS-3 through the permanent injection line. This brine will be supplemented with fresh water delivered by the water injection pump at the power plant.

The separated steam and water phases after high pressure separation will be metered through orifice type flow meters prior to throttling.

The facility also includes a bypass line discharging to an atmospheric flash tank\muffler. The well will be initially discharged through this bypass for not more than 4 hours to clean out drill cuttings and rock fragments.

The drilling rig will remain rigged up over the well with full crew during the flow test. Two kill lines will be hooked up between the rig mud pumps and the two 3 inch side outlets on the wellhead. Four hundred barrels of mud will be maintained in the mud pit for immediate pumping into the well as needed. In addition, a cementing unit and supplies to mix and pump 300 cubic feet of cement will be maintained on site during the test.

2.4 KS-8 Flow-test Procedures

2.4.1

Flow through the bypass to the atmospheric separator\muffler for no more than four hours. The 10" 1500# gate valve coming off the flow tee will be used to throttle the flow from KS-8. The flow will first be through a 10" 900# gate valve to the vent muffler located on Well Pad D to flush out the well. This flow will be abated with 50% caustic and water. Collect at least two steam and brine samples during the vent period using a small sampling separator.

2.4.2 Divert flow to the separators. Steam and brine from the well will be separated in separator 10-V-1A. Steam from separator 10-V-1A will be directed in a 16" line through a flow orifice before being treated for H_2S and discharged into the underground steam rock muffler located on Well Pad A. Brine from separator 10-V-1A will flow to separator 10-V-1A1 and then through a flow orifice manifold before discharging into an underground brine rock muffler.

2.4.3 Steam from separator 10-V-1A1 will mix with steam from the first separator downstream of the 16" flow orifice throttling valve before being treated with caustic. If KS-3 is used as an injector, the brine can be discharged into KS-3 without the need for a brine rock muffler or secondary flash. Raw water can be added to the brine if higher flow is required.

2.4.4 Operate the primary separator at 210 psig for the duration of the test. Flow well at four different rates over a wide range of wellhead pressures. Maintain each rate for a minimum of four hours or until discharge conditions stabilize. Run a pressure and temperature survey to TD with the well flowing at a rate approximately in the middle of the range. Record pressures, temperatures and flow rates around the facility every half hour. Collect two steam and brine samples at each flow condition.

2.4.5 Throttle well back to a total flowrate of $\pm$20,000 lb/hr and hold for four hours. Maintain data recording and sampling frequency as above.

2.4.6 Increase rate to design condition and flow at constant rate for remainder of ten day test (estimated $\pm$8 days).

2.4.7 Prior to shut in run a pressure and temperature survey to TD. Hang the instruments opposite the production zone and shut-in the well. Maintain the instruments downhole for a minimum of eight hours after shut-in.

2.5 Post Test Surveys

Run Pressure and temperature surveys 1, 2, 4 and 10 days after the test as disassembly and moving of the rig allows.

3 H_2S ABATEMENT PLAN

3.1 Introduction

Two periods of abated flow will occur during the KS-8 well test. During the initial period, geothermal brine will be directed through an atmospheric flash tank\muffler located on Well Pad D in close proximity to the KS-8 wellhead (Figure 2-1). This flow period will last no more than 4 hours. At the end of the initial flow period, the geothermal brine will be diverted to the main separators located on Well Pad A for the start of the long-term test period. This flow period will last for up to ten days.

3.2 H_2S Abatement Process

H_2S is removed from the steam by adding an aqueous solution of sodium hydroxide. The reaction is as follows:

$$H_2S + NaOH <-> NaHS + H_2O$$
$$H_2S + 2NaOH <-> Na_2S + 2H_2O$$

The sodium hydroxide solution is injected into the flow line using chemical metering pumps, which allow the operator to precisely control the injection rate.

The reaction only takes place in the presence of water. Between 50 and 350 gallons of water per minute will be injected into the flow line along with the sodium hydroxide.

The H_2S emission rate is verified by determining the mass flow rate of H_2S into the atmosphere. This flow rate is the product of the steam mass flow rate and the H_2S concentration:

$$H_2S \text{ (lb/hr)} = \text{Steam (lb/hr)} \times H_2S \text{ (concentration)}$$

The steam flow rate is being measured continuously during the test using a critical flow orifice during flow to the flash tank and an orifice metering run for flow from the separators. H_2S concentration is determined at regular intervals as described in Section 3.4.

3.3 Steam Sampling Procedures

3.3.1 Steam Sampling from the Atmospheric Flash Tank

To measure the H_2S concentration of steam emitted to the atmosphere, steam samples are taken directly from the atmospheric flash tank. A sampling probe is mounted inside the flash tank stack. Steam is withdrawn by a vacuum pump, condensed, and collected in an impinger. The sample is analyzed for H_2S according to the method described in Section 3.4 and Appendix A.

To measure the H_2S concentration in the steam before treatment, steam samples are taken using a mini separator located upstream of the caustic and water injection ports on the flow line (Figure 3-1).

3.3.2 Sampling of Steam Flow from Main Separators

Steam from the main separators is piped to a subsurface rock muffler where it is released to the atmosphere. To measure the H_2S concentration of steam emitted to the atmosphere, steam samples are taken directly from the rock muffler. A stainless steel sampling tube is buried in the rock muffler a few feet from the surface. Steam is drawn by a vacuum pump from the rock muffler and analyzed according to the procedure described in Section 3.4 and Appendix A.

To measure the H_2S concentration in the steam before treatment, steam samples are taken upstream of the orifice metering run on the main steam line (Figures 2-2, 3-2).

3.4 H_2S Analytical Procedure

There is no known method or instrument that can accurately measure the concentration of gases in saturated steam on a continuous basis. Instead, discrete samples of steam are withdrawn at regular intervals. The samples are then immediately analyzed for H_2S concentration using a proven analytical method. The test method employed is the Silver Nitrate Potentiometric Determination. (See Appendix A for test procedure.)

To determine H_2S concentration, the steam sample is condensed and bubbled through a solution of sodium hydroxide. The H_2S

is chemically trapped in the hydroxide solution. The sample bottle is weighed before and after the sampling procedure, allowing the precise weight of condensed steam to be determined. The weight of H_2S in the sample is determined by a chemical titration. Silver nitrate of a known concentration is slowly added to the sample. The silver nitrate removes H_2S from the solution by reacting with it to form an insoluble salt. An electrode placed in the solution alerts the technician when excess silver ions are present, indicating that all of the H_2S has been removed. Since the reaction between silver ions and H_2S is well understood, the amount of silver nitrate used during the titration can be related to the amount of H_2S removed. The ratio of H_2S to total sample is equal to the concentration of H_2S in the steam.

3.4 Abatement Efficiency and Expected Emission Levels

3.4.1 Abatement During Initial Flow Period

During the initial four hour flow period, all flow will be directed through the atmospheric flash tank located on Pad D. The maximum expected geothermal fluid flow rate is approximately 500,000 pounds/hour. This results in a steam flow rate of 400,000 pounds/hour assuming 80% flash at atmospheric pressure. The steam fraction is assumed to have an H_2S concentration of 625 parts per million (ppm). This concentration is derived from the numerous chemical analyses performed during the KS-3 well test and is consistent with modelling of atmospheric H_2S levels measured during the KS-8 uncontrolled flow of June 12-14, 1991. The rate of H_2S production is given by:

$$\left(\frac{400{,}000\ lb\ steam}{hr}\right)\left(\frac{625\ ppm\ H_2S}{10^6}\right) = \frac{250\ lb\ H_2S}{hr}$$

H_2S abatement efficiency is expected to be 96%. This value was derived empirically as a function of the mole ratio of NaOH to H_2S from data gathered during the KS-3 well test. The KS-3 test results indicate that this value is readily achievable using the abatement equipment proposed for the well test. The amount of H_2S to be removed based on this efficiency is:

$$\left(\frac{250\ lb\ H_2S}{hr}\right)(0.96) = \frac{240\ lb\ H_2S}{hr}$$

This level of abatement results in an emission rate of 10 pounds per hour of H_2S to the atmosphere for the initial four hour period.

A mole ratio of 8.4 moles NaOH per mole of abated H_2S is required to achieve the 96% efficiency level. This mole ratio determines the NaOH pumping rate required under the well test conditions as follows:

$$\left(\frac{8.4\ mole\ NaOH}{1\ mole\ H_2S}\right)\left(\frac{40\ lb\ NaOH}{1\ mole\ NaOH}\right)$$
$$\left(\frac{1\ mole\ H_2S}{34\ lb\ H_2S}\right)\left(\frac{1\ gal\ 50\%\ sln}{6.38\ lb\ NaOH}\right)\left(\frac{240\ lb\ H_2S}{hr}\right)$$

$$= \frac{372\ gal\ 50\%\ NaOH\ solution}{hr}$$

The proposed installed NaOH pumping capacity of 400 gallons per hour will therefore be more than adequate to achieve the abatement level described above.

The brine fraction of approximately 100,000 pounds/hour (208 gpm) will be discharged from the flash tank into an unlined pond and will be allowed to percolate into the porous rock below. H_2S emissions from the brine separated at atmospheric pressure will be negligible.

3.4.2 Abatement During Flow to the Separators

During the long-term flow period lasting up to 10 days, the geothermal fluid will be directed to the main separators on Well Pad A (Figure 2-1, 2-2). The fluid will be flashed to approximately 210 psi in the first separator. Separated brine from this

flash will be flashed again in the second separator to a pressure of approximately 20 psi. The steam flow from both separators will contain virtually all of the H_2S. The steam flow is directed to the subsurface rock muffler for discharge to the atmosphere. The caustic injection point is located on the steam line leading to the rock muffler. The injection point is downstream of the low pressure steam inlet to the main steam line such that all steam produced from the two flashes is abated.

H_2S emissions to the atmosphere during the long-term flow period is limited by permit to 5 pounds/hour. The flow from KS-8 will be throttled to the point where the abatement system and efficiency will meet this emissions limitation. The maximum mass flow rate from the well that is allowable under these conditions can be calculated. The following calculation of Q, the maximum allowable mass flow rate, is based on the same assumptions described in Section 3.4.1, i.e. 96% abatement efficiency for an 8.4:1 mole ratio of caustic to H_2S removal, an 80% steam fraction, and an H_2S content of 625 ppm in the steam:

$$Q = \left(\frac{5\ lb\ H_2S\ emitted}{hr}\right)\left(\frac{1\ lb\ geofluid}{0.8\ lb\ stm}\right)\left(\frac{10^6\ lb\ stm}{625\ lb\ H_2S\ total}\right)$$
$$\left(\frac{1\ lb\ H_2S\ total}{0.04\ lb\ H_2S\ emitted}\right) = \frac{250{,}000\ lb\ geofluid}{hr}$$

The mass flow rate will initially be throttled to 250,000 pounds/hour. As H_2S emissions data is gathered during the first hours of flow through the separators, the mass flow rate and caustic injection rate will be modified so that the 5 pound/hour emission rate is not exceeded.

The quantity of H_2S abated at this flow rate is given by:

$$\left(\frac{200{,}000\ lb\ stm}{hr}\right)\left(\frac{625\ lb\ H_2S}{10^6\ lb\ stm}\right)(0.96\ abatement\ eff.)$$

$$= \frac{120\ lb\ H_2S}{hr}$$

The caustic flow rate required for this level of abatement is calculated by:

$$\left(\frac{120\ lb\ H_2S}{hr}\right)\left(\frac{1.55\ gal\ 50\%\ sln}{1\ lb\ H_2S\ abated}\right)$$

$$= \frac{186\ gal\ 50\%\ sln}{hr}$$

This flow rate is easily accommodated by the 260 gallon/hr caustic pump capacity installed on the main steam line.

The brine separated from the second flash will be discharged to a separate subsurface rock muffler located on Well Pad A (Figure 2-1). The brine flow rate is estimated to be approximately 100 gpm. The H_2S content of the brine is expected to be negligible and will therefore not be abated.

3.5 Abatement Procedures

3.5.1 Estimate what the steam flow rate and H_2S concentration in the steam will be at the beginning of the test. Based on this estimate, calculate the sodium hydroxide injection rate at a 8.4:1 mole ratio.

3.5.2 When the test starts, begin injecting sodium hydroxide immediately based on the estimate. Also, begin water injection immediately.

3.5.3 Perform an after-treatment H_2S concentration test, calculate steam mass flow in pounds per hour, and calculate the emission rate of H_2S in pounds per hour.

3.5.4 If emissions are out of compliance, increase injection of sodium hydroxide or throttle back the well.

3.5.5 Immediately withdraw another steam sample and analyze for H_2S.

3.5.6 Continue this cycle of adjust-then-retest until emissions are in compliance.

3.5.7 Sampling Frequency

Follow procedure items 3 through 6 each hour after the beginning of flow to the separators. Test until two successive steam flow measurements are within ten percent of one another. At this point follow procedure items 3.5.3 through 3.5.6 four times per day at regular intervals. Additional tests will be made when significant changes in the resource occur or if the flow rate is altered.

3.6 Record Keeping

3.6.1 Records will be written in ink, using a permanently bound notebook. All pages will be numbered.

3.6.2 An entry will be made into the record book documenting each H_2S test that demonstrates compliance has been met. These tests will be numbered sequentially. No fewer than four entries per day will be made. Additional entries will be made when significant changes in the resource occur.

3.6.3 Data in the record book will include:

- Date
- Time
- Steam flow rate (pounds per hour)
- H_2S concentration (ppm) upstream and downstream of chemical injection
- H_2S concentration (ppm) and flow rate (pounds per hour) downstream of chemical injection
- Sodium hydroxide injection rate
- Sodium hydroxide storage volume on location
- A check box to acknowledge that the H_2S detector has been checked for zero and span
- comments and operators initials

3.7 Caustic Storage on Site

A minimum of three days supply of 50% caustic solution will be maintained on site throughout the well test. At a caustic consumption rate of 186 gallons per hour, this amount is 13,400 gallons of caustic.

4 GEOTHERMAL FLUID AND GAS CHEMISTRY PROGRAM

4.1 Introduction

The sampling and testing procedures for well KS-8 will not differ greatly from the programs conducted at other geothermal facilities throughout the world with the exception that the objectives for this relatively short term test of up to 10 days are considerably more extensive and comprehensive than would be encountered in most geothermal programs. The scope of the sampling program will satisfy the requirements of regulatory agencies, process engineering design and reservoir management.

The sampling and testing procedures will provide representative samples for analysis and subsequent interpretation and modeling. Testing procedures will verify that the flow streams are stabilized both in terms of pressure-temperature transients as well as chemical transients prior to obtaining samples that are truly representative of the flow streams expected under the various testing and operational scenarios. These verifications will be made through a combination of implementing industry accepted sampling procedures, sample preservation techniques and on-site analysis of selected constituents to verify stable flow and sampling conditions.

4.2 Description of the Chemical Program

The following sections address the specific needs of each of the three endpoint users of data supplied by this testing and sampling program. The final section will briefly describe the sampling system.

4.2.1 Environmental and Health Monitoring

Analysis of potentially hazardous geothermal constituents are outlined in a transmittal from PGV to the Hawaii State Department of Health dated October 28, 1991 (Table 4-1).

The detection limits specified for these constituents are included in Table 4-1. At the low detection limits specified by this requirement, stringent procedures will be implemented to assure that contamination from outside sources does not bias these samples.

The trace components listed in the windshield deposit (Table 4-2) and the emissions estimate of trace elements made by Reynolds (Table 4-3 and 4-4) should be addressed as potential environmental concerns. Since many of these metals are common both to the production casing and the sampling system, particular care will be taken to minimize such contamination sources or to identify these external sources of any metals detected. Analyses of blank samples and analyses of any preservative reagents will be checked prior to reaching conclusions on the level of metal contents in the resource.

Finally, the levels of any constituent that may be established as a concern relative to the geothermal emissions should also be determined within the background environment. For example, a scan of the constituents listed in Tables 4-3 and 4-4 indicates a number of species that are common to seawater and basaltic volcanic environments. The typical amounts of such constituents associated with tradewind rainfall or wind borne soil dusts should be examined within the context of establishing hazard levels of potential geothermal aerosols or particulates.

4.2.3 Engineering Design Monitoring

The low pH chemistry of KS-3 raises concern relative to existing design engineering and the ability of the process system to handle the potential corrosion associated with such fluids. These concerns range from corrosion in the production casing to corrosion within the brine handling system. Pipe line corrosion will be monitored during the test by the collection of field pH measurements and by the analysis of brine samples to determine the iron and manganese contents of the produced fluids.

The scaling potential of the system will be investigated during the test. Measurements of scale thickness and speciation will be conducted as a post flow analysis of the system. The scaling potential of the system as a function of changing flow rates and changing pressures will be determined by utilizing a time series of analyses and evaluating the ion ratios of potential scale forming species such as silica or calcium versus conservative species such as chloride. Analysis of the scales for potential toxic hazards will be part of the scale characterization program.

Scale formation or mineral precipitation as a consequence of mixing of flow streams will be evaluated in a qualitative fashion using either side stream or jar tests of brines and mixtures of other process streams such as the non-condensible gases, quenched steam, or water from the drilling supply well as appropriate.

4.2.4 Reservoir Evaluation

Variations in the chemistry of produced fluids, both spatially and temporally, have provided some insight to the nature of the reservoir system at Puna. Some of the significant variations that have been noted to date include the increased sea water fraction present in HGP-A through the duration of production, the variations in chemistry reported in KS-1A as a function of wellhead pressures, and the chemical transients associated with changes in flow rate that were noted in the KS-3 flow test. These chemical transients suggest that both long term and short term variations in the deep systems exist at Puna. Mixing of sea water and fresh water and the interaction of these systems with shallow basaltic dike swarms contribute to these variations.

The KS-8 flow test will provide a baseline chemistry for this well during commercial production. If the well behaves as other wells in the system, it is likely that variations in chemistry as a function of flow

rate through the testing period will provide some insight into the interaction of this well with the many components of the natural system. These interactions may allow prediction of trends to either changes in enthalpy with time or mixing of the various sources of production fluids that have been identified with this system. In particular, indications of acid fluids associated with sea water-basalt reactions may pose a concern for future production. In contrast, confirmation of benign chemistry with no transients to problem fluid compositions or enthalpies will provide confidence in optimizing production in a timely manner.

4.2.5 Sampling System

Access to geothermal process stream and extraction of representative samples has been addressed extensively in the geothermal literature. Sampling of two phase systems is particularly difficult and poses numerous problems in obtaining representative samples. Empirical guidelines, determined in some cases by trial and error, have established preferred locations for obtaining representative flows. PGV utilized guidelines established by Thermochem for the placement of two phase and single phase flush sample ports as shown in Figure 2-2.

Since there is some concern in the environmental samples for the presence of base metals and transition element metals, the sample port valving and sampling system will be constructed of stainless steel. All bushings, throttling valves and metering valves will be stainless or carbon steel construction. Galvanized or brass material will be avoided.

4.3 Sampling Procedures

Sampling procedures are critical to any sampling program. The needs of each of the individual sampling objectives, outlined above, require unique samples. These requirements are discussed in the following sections.

4.3.1 Environmental and Health Samples - Steam Line

4.3.1.1 Metal Analysis: Condensed steam, filtered, preserved with 5 mls of concentrated HNO_3 per 250 mls of sample. Sample bottles will be pre-rinsed with a similar ratio of HNO3 and deionized water prior to sampling. Bottles and caps will be rinsed twice with the condensed steam prior to adding the sample and preserving acid. Collect two 250 ml samples in polyethylene bottles.

4.3.1.2 Mercury Analysis: Condensed steam, raw sample, preserved with a mixture of 1 gram of $K_2Cr_2O_7$ in 100 mls of concentrated HNO_3 added to the sample in a ratio of 1:4. Collect 100 mls of sample with 25 mls of preservative in a 125 ml amber bottle with polyseal cap.

4.3.1.3 Anion Analysis: Condensed steam, raw sample. Bottles caps will be rinsed twice with the condensed steam prior to adding the sample. Collect two 250 ml samples in polyethylene bottles.

4.3.1.4 Non-condensible Gas Analysis: Collect 2 samples in evacuated gas bombs per Thermochem instructions. Total gas samples will be preserved with NaOH solution. Hydrocarbon sample will be preserved with NaOH + $CdCl_2$ solution.

4.3.1.5 Field measurement of pH of condensate.

4.3.2 Environmental and Health Samples - Brine Line

4.3.2.1 Metal Analysis: Cooled brine, filtered, preserved with 5 mls of concentrated HNO_3 per 250 mls of sample. Sample bottles will be pre-rinsed with a similar ratio of HNO3 and deionized water prior to sampling. Bottles and caps will be rinsed twice with the condensed steam prior to adding the sample and preserving acid. Collect two 250 ml samples in polyethylene bottles.

4.3.2.2 Anion, pH, TDS, TSS, metalloid analysis:

Cooled brine, raw, filtered if sample is turbid. Bottles and caps will be rinsed twice with the cooled brine prior to adding the sample. Collect two 250 ml samples in polyethylene bottles.

4.3.2.3 Silica Analysis: Cooled brine, filtered and diluted at a ratio of 1:10 with a 2% HNO_3 solution. Rinse bottle and cap with sample fluid. Add 10 mls sample to 90 mls solution and store in a 125 ml polyethylene bottle.

4.3.2.4 Sulfide Analysis: Cooled brine, raw, preserved with a NaOH + $CdCl_2$ solution. Rinse bottle and cap with sample fluid. Collect one 250 ml sample in polyethylene bottle.

4.3.2.5 Ammonia Analysis: Cooled brine, raw sample. Collect in amber 125 ml bottle with polyseal cap. Rinse the bottle twice with sample fluid.

4.3.2.6 Field measurement of pH.

4.3.3 Sample quality control

The sample suite obtained, as described above, will be sufficient to characterize the fluid at the time of sampling. To insure that these samples are adequate for production fluid characterization, several quality control and field checks will be made:

4.3.3.1 Even though the reagents used in these procedures are high purity, an analytical blank for all reagents and diluting solutions will be included as part of the analytical scheme.

4.3.3.2 Prior to collecting any of the more extensive and comprehensive sample suites, field measurements of conductivity or diluted conductivity will be made on both steam condensates and brines to insure that the separating and collecting facilities are being operated in a stable manner. If the system is, for example, obviously surging, then the

sample suites will have little value in bracketing the true reservoir composition. The production system will be adjusted to dampen the effects of such transients within the process system.

4.3.3.3 As an additional verification of stability of the system and that the samples are representative, these detailed sample suites, which may take several hours to collect, will be made part of a time series in which the brine lines are samples on one hour intervals for several hours prior to and subsequent to the primary sampling. These samples will be analyzed with the standard ICP scan and anion analysis at UURI. At this time, field analyses of components such as conductivity, chloride, and silica will be used to verify the representative nature of the flow stream.

4.3.3.4 These sample suites will be repeated over a several day interval. The probability that one or more of the components of the sample suite is either defective or lost is high. A surplus number of sample suites will be collected and held in reserve, in the event that questions or uncertainties arise from the primary set of sample analyses.

4.3.3.5 An additional set of samples and analyses will be required for all scales that are identified in the process system at the termination of the test. These samples occasionally contain levels of metals or metalloids at levels which may be of concern in terms of occupational safety. These samples will be screened for toxic species such as mercury and arsenic. A materials handling and disposal of waste program will be designed and implemented for these materials.

4.3.4 Engineering Design Samples

Many questions for design verification will be answered by the sample suites taken for environmental and health purposes. There are

additional questions on the performance of the plant facilities that can be evaluated during this test period. The following sample program will be implemented:

4.3.4.1 Evaluation of separator efficiency. The monitoring done to verify the stabilized flow for the system will provide guidelines for this sampling. If conductivities are higher than a few tens of microhoms, tests and samples to verify the source of the conductivity will be required. Dissolved NC gas may account for a large portion of the conductivity. Stripping of these gas by gentle heating to near boiling may provide a more accurate assessment of the brine carryover. Field analysis of these gas-stripped samples for silica or chloride will confirm the level of carryover. Spectrophotometric analysis will be utilized. If a significant carryover is present, the operational parameters of the separator may be varied and results checked with additional samples.

4.3.4.2 Evaluation of vapor transport of chloride or silica. Essentially the same test program as for separator efficiency should be conducted. Comparison of Na-Cl ratios in the steam versus in the brine will be required to verify transport of Cl as acid vapor. Low level analysis of raw steam condensate using ion chromatography will be utilized.

4.3.4.3 Evaluation of steam line corrosion. Samples collected from steam condensate blowdown from the drain pot steam traps will be checked for both pH and iron content. Spectrophotometric analysis will be utilized. If systematic changes in the iron content through the system is observed, or if significant iron is observed, samples will be submitted for complete analysis and a scrubbing system evaluated.

4.3.4.4 Brine line corrosion. The pH of the brine will be checked in the field.

Samples both near the separator and as far downstream as possible prior to NaOH injection will be obtained. Comparisons of the iron and manganese content and a comparison of these metals to chloride through the system could verify any major corrosion problems. Spectrophotometric analysis will be utilized.

4.3.4.5 Mineral precipitation due to mixing of flow streams. A sample of brine could be mixed with either a condensed steam-NC flow stream or be used to condense a steam-NC flow stream. The resulting mixture will then be filtered and the residue analyzed by XRDF, wet chemistry and microscopy to identify phases present.

4.3.4.6 Scaling tendency of the system. Filtered and acidified samples of the brine at both upstream and downstream locations will be compared for loss of potential scale forming species such as calcium, sulfate and silica. These constituents should be compared to a conservative element in the system, such as chloride, to evaluate scaling through the system.

4.3.4.7 Scaling rates within the system. Upon completion of the test, a systematic sampling of the entire flow system, from wellhead to disposal site will be conducted to evaluate scaling rates and products. These measurements and samples will be taken at the conclusion of the flow test and samples will be preserved in containers to prevent dehydration and oxidation. Analyses will be by XRDF and by wet chemical processes described in Appendix B. The steam process system, steam line, brine line and, if used, the turbine should be examined for scale formation as a result of corrosion products and also brine carryover.

4.3.4.8 Perform tests to characterize the solid loading of the injection system. These tests will provide a field estimation of the total suspended solids. A

generalized procedure for filtration is outlined in Appendix C. The washing, drying and weighing procedures can be conducted in the laboratory if necessary. These tests would be intended to make a decision on the necessity of filtering injectate prior to disposal. If time permits, a more rigorous membrane filter test should be conducted using guidelines described in Appendix B.

4.3.5 Reservoir Management

Much of the data required for reservoir analysis will be provided by the samples collected in the Environmental sampling program. There are some specific requirements that need to be implemented for this type of sampling. Chemical transients induced by changes in the flow rate or upset conditions in the production system often provide clues to the reservoir geometry and long term performance. During the testing of well KS-3, these transients were particularly evident when major changes in the flow rate were recorded. These transients were not always well documented in the KS-3 chemical sampling program since the program was not designed to track these features. The following sampling procedures will be utilized for reservoir analysis:

4.3.5.1 A regular sampling program at intervals of every 6 hours throughout the duration of the test. These samples will consists of the basic brine samples analyzed for the full suite of constituents including NH_3, Br and sulfide. A total gas sample taken in an evacuated gas bomb with a NaOH preservative will be collected every 12 hours.

4.3.5.2 Establish a field monitoring system to track the produced fluids for indications of chemical stability at a given flow rate. This will consist of monitoring silica and chloride in the brine. A decision to maintain a flow rate or to increase (or decrease) sampling frequencies could be based on

these samples.

4.3.5.3 If the flow rates are changed during the test, coordinate sampling to these changes so that the samples closely bracket these changes. Sampling during the KS-3 test did not always define the chemical conditions at a given flow rate. The field monitoring tests can help to define the sampling frequency during transient periods in the chemistry.

4.4 Summary

Although the sampling concepts briefly outlined above will require a significant cost and effort, these samples will allow PGV to better understand the system. Table 4-5 is a synopsis of the chemical sampling and testing program for the KS-8 flow test and tabulates the frequency of the sample collection. This data base will allow PGV to mitigate any potential concerns with environmental and health hazards and to mitigate any process or resource-related problem that may be detrimental to the success of the project.

5 AEROSOL CHEMISTRY PROGRAM

Potentially hazardous aerosol emissions from the steam released to the rock muffler will be investigated. The list of toxic elements that will be analyzed is shown in Table 4-1. The sampling will be done on the abated steam flow taken from a sample port near the discharge to the rock muffler. The sampling will follow the procedure described in Section 4.3.1.

6 POWER PLANT TEST PROGRAM (Figure 6-1)

The power plant test program is designed to test various components of the power plant generating, steam handling, and brine handling equipment. The power plant will be supplied with steam from KS-8 during the well test. The steam will be delivered to the plant from separator 10-V-1A operating at 210 psig. Execution of the KS-8 well test with discharge to the rock mufflers can proceed independently of steam delivery to the power plant. Because of this feature, the power plant can take steam on an as-needed and intermittent basis without interfering with the continuity of the KS-8 test.

6.1 Power plant steam requirements during testing are not expected to exceed 50,000 lb/hr.

6.2 Steam will be diverted to the power plant by opening the 20" gate valve on the separators outlet header.

6.3 If the power plant is not able to receive the steam sent from the separator, it can be diverted to the emergency steam release area for treatment before discharge.

6.4 Brine can also be pumped to the power plant using the brine injection pumps at the separators area to test the complete injection system. This will be done when KS-3 is being used for injection.

6.5 In the case where no brine flows to the power plant, combined condensate and NCG from the power plant will flow back to Well Pad A and discharge into the steam rock muffler after treatment for H2S. Raw water can be injected to increase flow. This condensate/NCG stream can also be combined with brine near the separators area for injection into KS-3.

6.6 If the recombined stream from the power plant consist of condensate, NCG and brine then it has to be injected into KS-3.

6.7 The well test with full flow of 250,000 lb/hr will be run concurrently with the power plant test for the full 10 days. The steam not required at the plant will be diverted to the steam rock muffler after abatement.

7 KS-3 INJECTION PROGRAM

7.1 Introduction

An injection test of KS-3 will be carried out in conjunction with the production test of KS-8. The injection fluid will consist of the separated production brine from KS-8 supplemented with fresh water as appropriate. The overall objective of the test will be to inject fluid continuously at the system wellhead pressure (WHP) of 150 psig for a period of up to 8 days.

The separated brine component of the injection fluid will be metered by an orifice-type flow meter installed on the brine outlet side of the KS-8 production separator (refer to KS-8 production test plan, Figure 2-2). The fresh water component will be supplied from the permanent water injection pump at the power plant. This component will be metered by a turbine-type flow meter installed on the downstream side of the pump. The total injection flowrate will be the sum of the two components.

7.2 Test procedures

7.2.1 Once steady production conditions have been established at KS-8 (anticipated to be approximately 2 days after commencement of the test), begin pumping fresh water into KS-3 at a nominal rate of about 100 gpm.

7.2.2 After injecting fresh water for 3 hours, begin diverting separated brine from the rock muffler to KS-3. Adjust the fresh water injection as necessary to keep the mixture below boiling point in the injection line and well.

7.2.3 Once all the brine has been diverted to KS-3, adjust the fresh water injection rate as necessary to maintain the WHP at KS-3 at 150 psig.

7.2.4 Continue injection at a steady WHP of 150 psig for a minimum of 2 days or until the injection rate stabilizes. Record injection rate (i.e. brine and fresh water rates), WHP and wellhead temperature (WHT) at minimum one hour intervals. Collect a sample of injection fluid twice per day.

7.2.5 After injection conditions stabilize, run a pressure/temperature/spinner (PTS) instrument with 12 hour clocks to 5,000 ft.

7.2.6 Pull up instruments to 4,000 ft. and hang. Reduce the injection rate until WHP is 10 psig and hold for 4 hours. Increase injection rate until WHP is 150 psig. Retrieve instruments when clocks expire.

7.2.7 Continue to inject at a steady WHP of 150 psig for the balance of the production test of KS-8. Record flowrate, WHP and WHT at minimum one hour intervals. Total duration of injection to KS-3 will be about 8 days. Revert to continuous bleed injection at conclusion of test to maintain well kill.

8 SCHEDULE

The schedule for the KS-8 well test and associated activities as described above is shown in Figure 8-1. The schedule is

dependent on the date of reinstatement of the PGV well field and drilling permits. The date for this event is given in the schedule as December 1, 1991. In the event that this date changes the entire schedule will shift accordingly.

9 LIST OF TABLES

10 LIST OF FIGURES

11 LIST OF APPENDICES

TABLE 4-1

PUNA GEOTHERMAL VENTURE

CHEMICAL ANALYSIS CHECKLIST FOR ATC COMPLIANCE OF GEOTHERMAL STEAM, STEAM CONDENSATE AND BRINE

LABORATORIES:	
BEI	Brewer Environmental Industries, Papaikou, HI
UURI	University of Utah Research Institute, Salt Lake City, UT
T-Chem	Thermochem, Santa Rosa CA

BRINE

ANALYTE	LAB	DETECT LIMIT	S.P.	DATE	TIME	I.D. No.	SAMPLER
Benzene	BEI	0.001 mg/l					
Ammonium	UURI	0.05 ppm					
Arsenic	UURI	0.005 mg/l					
Lead	UURI	0.002 mg/l					
Cadmium	UURI	0.005 mg/l					
Bicarbonates	UURI	1.0 ppm					
Carbonates	UURI	1.0 ppm					
Sulfates	UURI	1.0 ppm					
Chlorides	UURI	1.0 ppm					
Nitrate	UURI	0.01 ppm					
Hydrogen Sulfide	BEI	1.0 ppm					
Fluoride	UURI	0.05 ppm					
Mercury	UURI	0.0005 mg/l					
Total Dissolved Solids	UURI	4.0 ppm					
Total Suspended Solids	UURI	5.0 ppm					
pH	UURI	N/A					

STEAM CONDENSATE, UNABATED

ANALYTE	LAB	DETECT LIMIT	S.P.	DATE	TIME	I.D. No.	SAMPLER
Benzene	BEI	0.001 mg/l					
Ammonium	UURI	0.05 ppm					
Arsenic	UURI	0.005 mg/l					
Lead	UURI	0.002 mg/l					
Cadmium	UURI	0.005 mg/l					
Bicarbonates	UURI	1.0 ppm					
Carbonates	UURI	1.0 ppm					
Sulfates	UURI	1.0 ppm					
Chlorides	UURI	1.0 ppm					
Nitrate	UURI	0.01 ppm					
Hydrogen Sulfide	BEI	1.0 ppm					
Fluoride	UURI	0.05 ppm					
Mercury	UURI	0.0005 mg/l					
Total Dissolved Solids	UURI	4.0 ppm					
Total Suspended Solids	UURI	5.0 ppm					
pH	UURI	N/A					

STEAM CONDENSATE, ABATED

ANALYTE	LAB	DETECT LIMIT	S.P.	DATE	TIME	I.D. No.	SAMPLER
Benzene	BEI	0.001 mg/l					
Ammonium	UURI	0.05 ppm					
Arsenic	UURI	0.005 mg/l					
Lead	UURI	0.002 mg/l					
Cadmium	UURI	0.005 mg/l					
Bicarbonates	UURI	1.0 ppm					
Carbonates	UURI	1.0 ppm					
Sulfates	UURI	1.0 ppm					
Chlorides	UURI	1.0 ppm					
Nitrate	UURI	0.01 ppm					
Hydrogen Sulfide	BEI	1.0 ppm					
Fluoride	UURI	0.05 ppm					
Mercury	UURI	0.0005 mg/l					
Total Dissolved Solids	UURI	4.0 ppm					
Total Suspended Solids	UURI	5.0 ppm					
pH	UURI	N/A					

STEAM, NON-CONDENSIBLE GASES

ANALYTE	LAB	DETECT LIMIT	S.P.	DATE	TIME	I.D. No.	SAMPLER
% NC Gases	T-Chem	N/A					
Benzene	T-Chem	0.00028 ppm					
Hydrogen Sulfide	T-Chem	0.20 ppm					
Ammonia	T-Chem	0.10 ppm					
Radon 222	T-Chem	50 pCi/kg					
Mercury	T-Chem	0.001 ppm					
Carbon Dioxide	T-Chem	5.0 ppm					
Sulfur Dioxide	T-Chem	0.10 ppm					
Methane	T-Chem	0.2 ppm					
Total Hydrocarbons:	T-Chem						
Methane		0.2 ppm					
Ethylene		0.00006 ppm					
Ethane		0.00008 ppm					
Propylene		0.00007 ppm					
Propane		0.00007 ppm					
Isobutane		0.00008 ppm					
1-Butene		0.00006 ppm					
Butane		0.00008 ppm					
2,2-Dimethylpropane		0.0001 ppm					
2-Methylbutane		0.00008 ppm					
1-Pentane		0.00006 ppm					
Pentane		0.00007 ppm					
2,2-Dimethlpentane		0.00007 ppm					
2 and 3-Methylpentane		0.00009 ppm					
Hexene		0.00006 ppm					
Hexane		0.00008 ppm					
Additional Hydrocarbons		N/A					

TABLE 4-2
COMPONENTS OF WINDSHIELD DEPOSITS
PGV REPORT, ELEMENT III, PART I

COMPONENT	VALUE	UNITS
Lead	678	ppmw
Nickel	90	ppmw
Chromium	72	ppmw
Manganese	118	ppmw
Copper	16.3	ppmw
Zinc	19.2	ppmw
Arsenic	<10	ppmw
Iron	6.53	%
Aluminum	1.56	%

TABLE 4-3
ESTIMATES OF STEAM COMPOSITION
KS-3 AND KS-1A
PGV REPORT, ELEMENT III, PART I

COMPONENT	LOWER	UPPER	UNITS
Hydrogen Sulfide	493	1200	ppmw
Ammonia	0.168	1.49	ppmw
Arsenic	N/A	N/A	
Lead	N/A	N/A	
Cadmium	N/A	N/A	
Chlorides	N/A	N/A	
Boron	N/A	N/A	
Mercury	N/A	N/A	
pH	N/A	N/A	
Total Dissolved Solids	N/A	N/A	
Total Suspended Solids	N/A	N/A	
Nickel	N/A	N/A	
Chrome	N/A	N/A	

TABLE 4-4
ESTIMATES OF STEAM COMPOSITION USING
KS-1A PRE-FLASH AND POST FLASH VALUES
PGV REPORT, ELEMENT III, PART I

COMPONENT	POST FLASH	TOTAL BRINE	STEAM	UNITS
Arsenic	0.49	0.1	0.00182	ppmw
Mercury	0.0017	0.0003	0.00005	ppmw
Boron	8.43	1.7	0.00591	ppmw
Silica	1170	235.27	0.02128	ppmw
Aluminum	<2.50	<0.5	N/A	ppmw
Barium	32.3	6.5	0.00560	ppmw
Manganese	8.13	1.63	0.00619	ppmw
Chloride	18,500	3,720	0.36299	ppmw
Fluoride	0.91	0.18	0.00548	ppmw
Sulfate	14.2	2.86	0.00548	ppmw
Total Dissolved Solids	33,100	6,656	0.65089	ppmw

TABLE 4-5
PUNA GEOTHERMAL VENTURE
FLOW TEST KS-8
FREQUENCY OF CHEMICAL SAMPLING AND ANALYSIS

ENVIRONMENTAL AND HEALTH

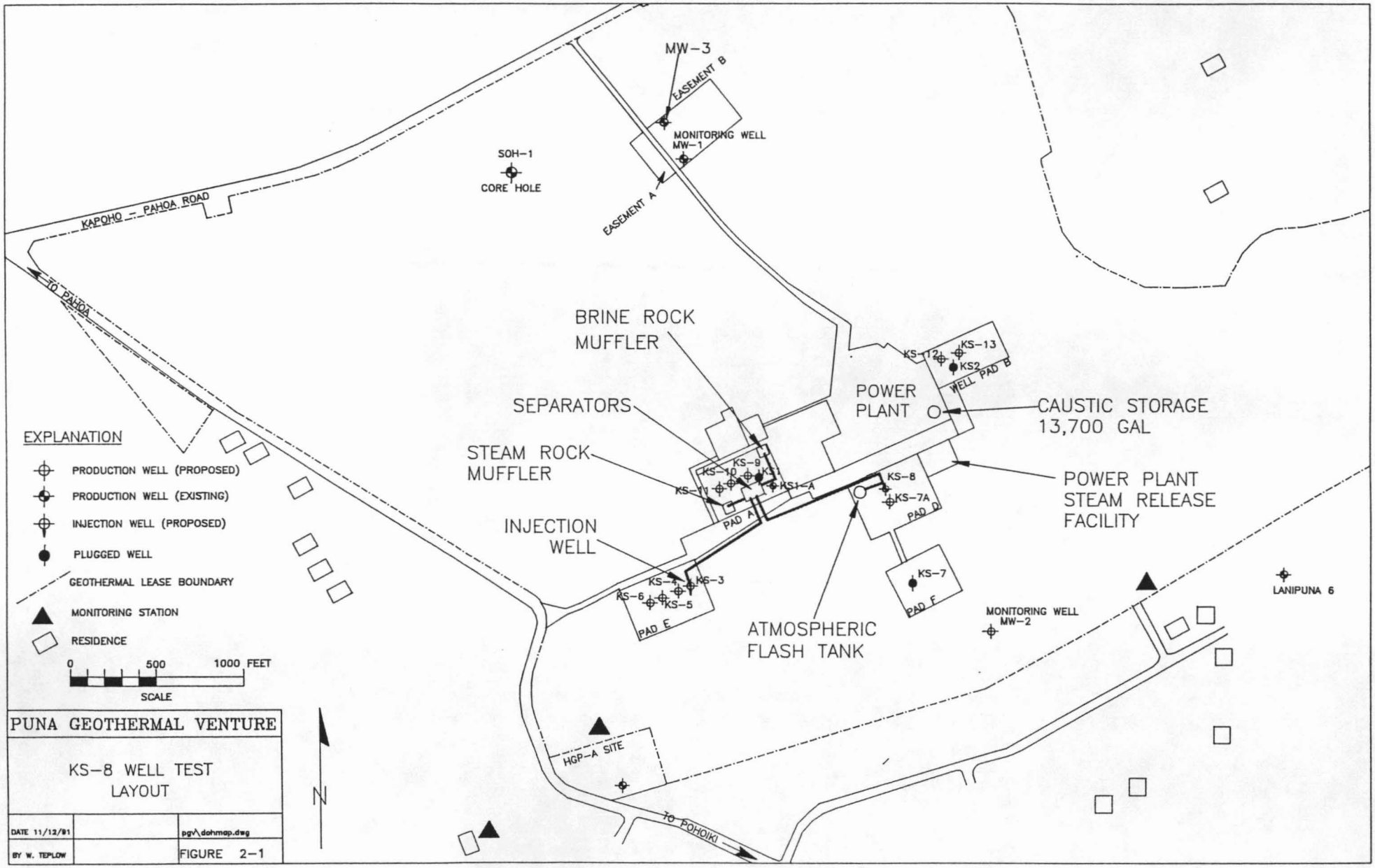
SAMPLE DESCRIPTION	ANALYSIS	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	DAY 10
1. Steam Condensate											
a. metals	LAB		1			1			1		
b. anions	LAB		1			1			1		
c. mercury	LAB		1			1			1		
d. NC gases	LAB		1			1			1		
2. Brine											
a. metals	LAB		1			1			1		
b. anions, TDS	LAB		1			1			1		
metalloids	LAB		1			1			1		
c. silica	LAB		1			1			1		
d. sulfide	LAB		1			1			1		
e. ammonia	LAB		1			1			1		
f. TSS	LAB		1			1			1		

RESERVOIR EVALUATION

SAMPLE DESCRIPTION	ANALYSIS	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	DAY 10
1. Brine:ICP+anions	LAB	4	3	4	4	3	4	4	3	4	4
2. NC Gases	LAB	2	1	2	2	1	2	2	1	2	2

ENGINEERING DESIGN

SAMPLE DESCRIPTION	ANALYSIS	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	DAY 10
1. Brine line corrosion											
a. pH, Cl, Si, Fe, Mn	FIELD	2	2	2	2	2	2	2	2	2	2
b. ICP+anions @ 2nd station	LAB		1			1				1	
2. Steam line corrosion pH, Cl, Fe, Mn	FIELD			1		1		1		1	
3. Separator Efficiency pH, Cl, Si, conductivity	FIELD	1	1	1	1	1	1	1	1	1	1
4. Steam Purity Ion chromatography	FIELD	1		1	1		1	1		1	1
4. Filtration Test	LAB				1			1			1
5. Jar Test	FIELD/LAB			1			1			1	


MW-3
EASEMENT B
MONITORING WELL MW-1
SOH-1
CORE HOLE
EASEMENT A
KAPOHO - PAHOA ROAD
TO PAHOA
BRINE ROCK MUFFLER
SEPARATORS
STEAM ROCK MUFFLER
INJECTION WELL
KS-12
KS-13
KS2
WELL PAD B
POWER PLANT
CAUSTIC STORAGE 13,700 GAL
POWER PLANT STEAM RELEASE FACILITY
KS-9
KS-10
KS-11
KS-1
KS-1A
PAD A
KS-8
KS-7A
PAD D
KS-7
PAD F
KS-4
KS-3
KS-6
KS-5
PAD E
ATMOSPHERIC FLASH TANK
MONITORING WELL MW-2
LANIPUNA 6
HGP-A SITE
TO POHOIKI
EXPLANATION
PRODUCTION WELL (PROPOSED)
PRODUCTION WELL (EXISTING)
INJECTION WELL (PROPOSED)
PLUGGED WELL
GEOTHERMAL LEASE BOUNDARY
MONITORING STATION
RESIDENCE
0
500
1000 FEET
SCALE
N
PUNA GEOTHERMAL VENTURE
KS-8 WELL TEST LAYOUT
DATE 11/12/91
BY W. TEPLOW
pgv\dohmap.dwg
FIGURE 2-1

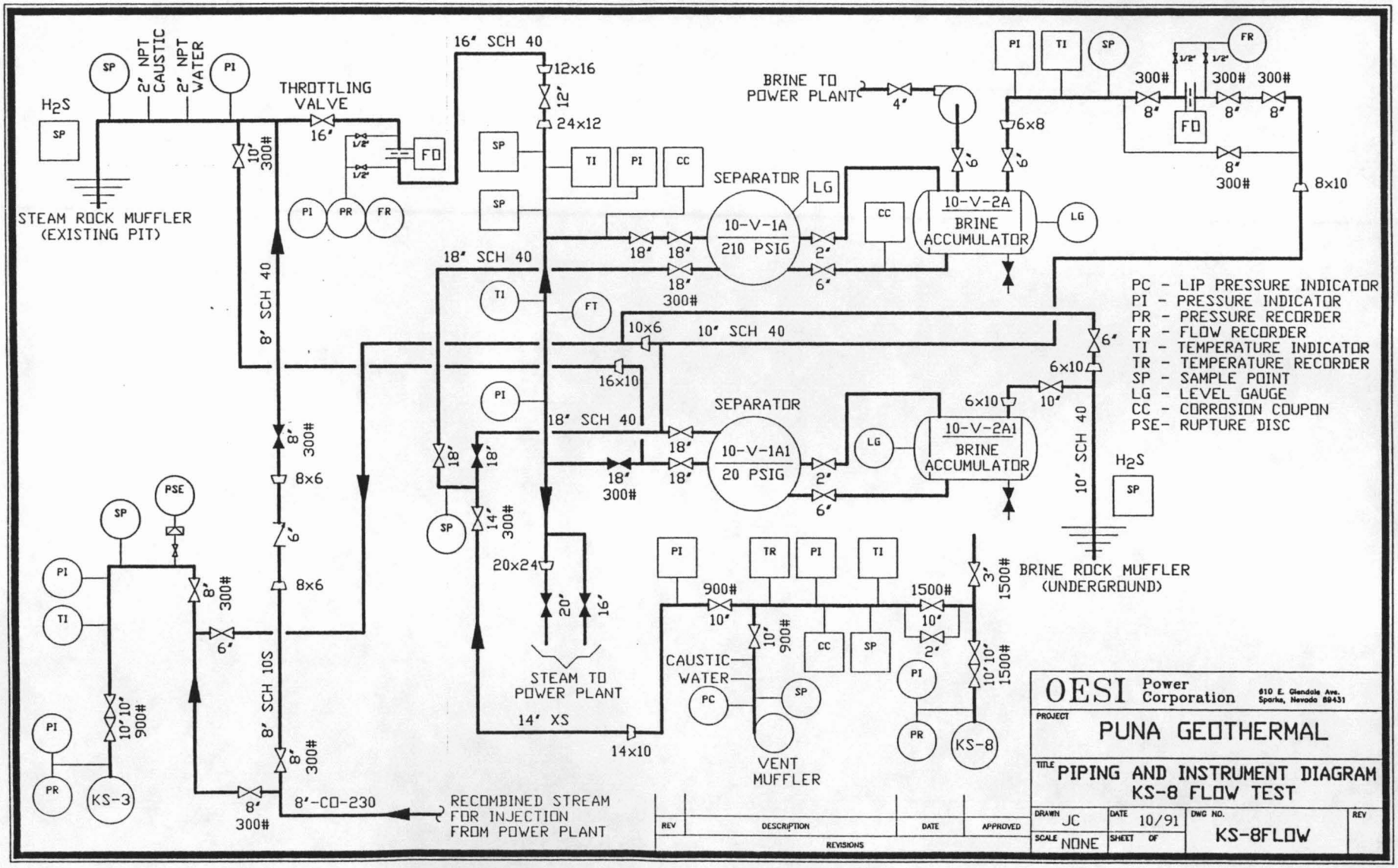
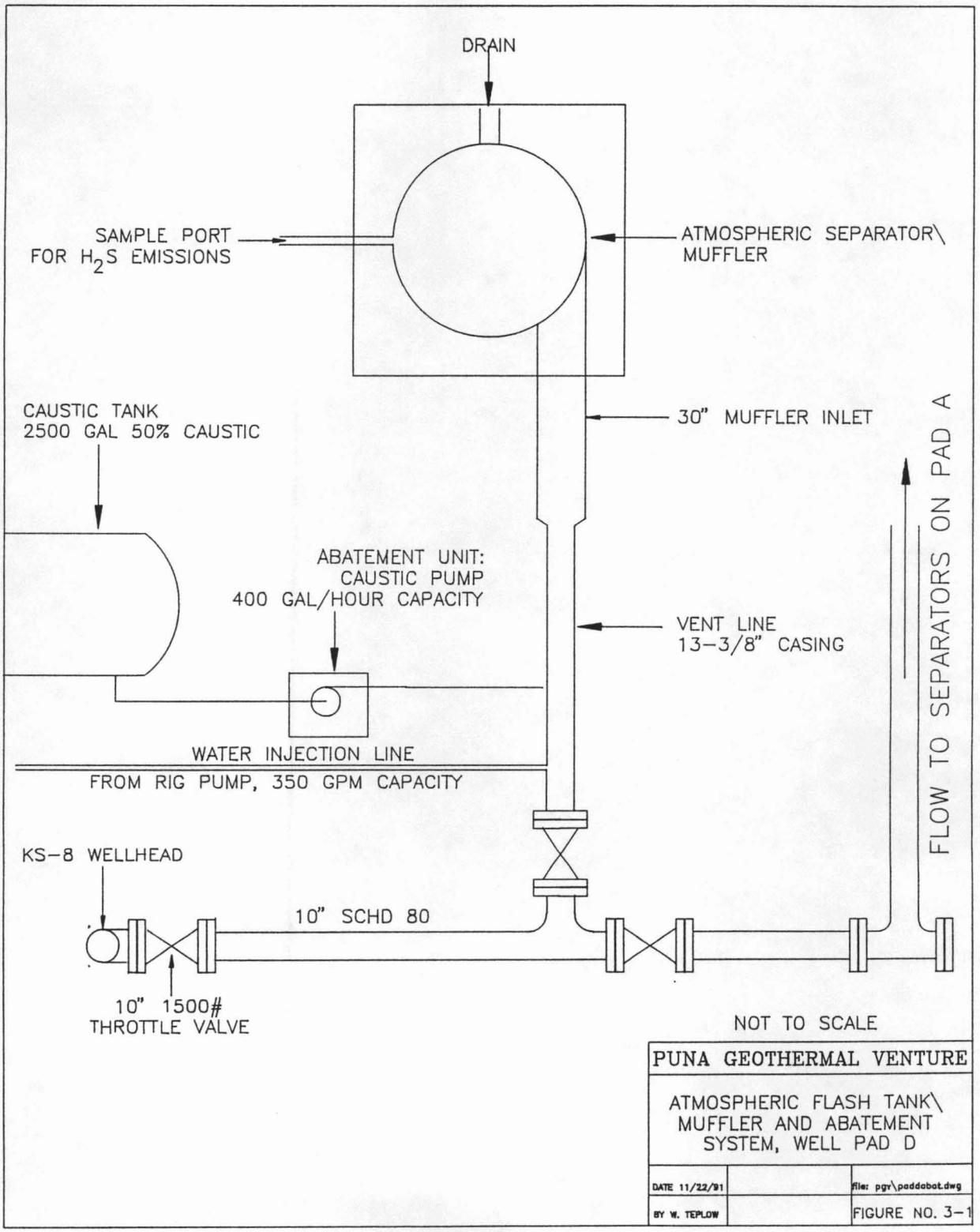
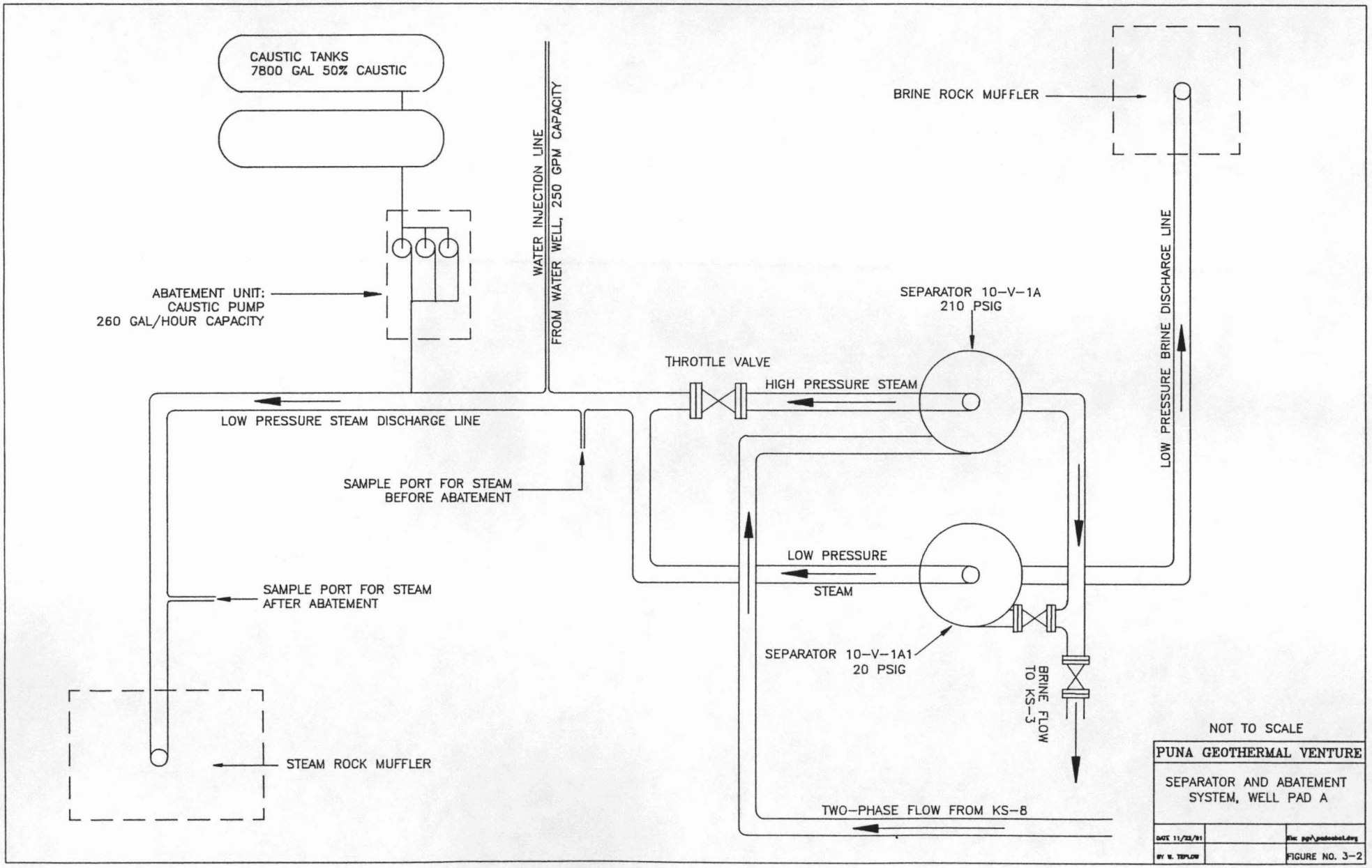

H2S
2" NPT CAUSTIC
2" NPT WATER
THROTTLING VALVE
STEAM ROCK MUFFLER (EXISTING PIT)
16" SCH 40
12x16
24x12
BRINE TO POWER PLANT
SEPARATOR
10-V-1A
210 PSIG
10-V-2A
BRINE ACCUMULATOR
18" SCH 40
10x6
10" SCH 40
16x10
SEPARATOR
10-V-1A1
20 PSIG
10-V-2A1
BRINE ACCUMULATOR
8" SCH 40
8" SCH 10S
20x24
STEAM TO POWER PLANT
14" XS
14x10
CAUSTIC
WATER
VENT MUFFLER
BRINE ROCK MUFFLER (UNDERGROUND)
8"-CD-230
RECOMBINED STREAM FOR INJECTION FROM POWER PLANT
KS-3
KS-8
PC - LIP PRESSURE INDICATOR
PI - PRESSURE INDICATOR
PR - PRESSURE RECORDER
FR - FLOW RECORDER
TI - TEMPERATURE INDICATOR
TR - TEMPERATURE RECORDER
SP - SAMPLE POINT
LG - LEVEL GAUGE
CC - CORROSION COUPON
PSE- RUPTURE DISC
OESI Power Corporation
610 E. Glendale Ave. Sparks, Nevada 89431
PROJECT PUNA GEOTHERMAL
TITLE PIPING AND INSTRUMENT DIAGRAM KS-8 FLOW TEST
DRAWN JC
DATE 10/91
DWG NO. KS-8FLOW
REV
SCALE NONE
SHEET OF
REVISIONS
REV DESCRIPTION DATE APPROVED

FIGURE 2 - 2


DRAIN
SAMPLE PORT
FOR H_2S EMISSIONS
ATMOSPHERIC SEPARATOR\
MUFFLER
CAUSTIC TANK
2500 GAL 50% CAUSTIC
30" MUFFLER INLET
FLOW TO SEPARATORS ON PAD A
ABATEMENT UNIT:
CAUSTIC PUMP
400 GAL/HOUR CAPACITY
VENT LINE
13-3/8" CASING
WATER INJECTION LINE
FROM RIG PUMP, 350 GPM CAPACITY
KS-8 WELLHEAD
10" SCHD 80
10" 1500#
THROTTLE VALVE
NOT TO SCALE
PUNA GEOTHERMAL VENTURE
ATMOSPHERIC FLASH TANK\
MUFFLER AND ABATEMENT
SYSTEM, WELL PAD D
DATE 11/22/91
file: pgv\paddabat.dwg
BY W. TEPLOW
FIGURE NO. 3-1


CAUSTIC TANKS
7800 GAL 50% CAUSTIC
ABATEMENT UNIT:
CAUSTIC PUMP
260 GAL/HOUR CAPACITY
WATER INJECTION LINE
FROM WATER WELL, 250 GPM CAPACITY
BRINE ROCK MUFFLER
LOW PRESSURE BRINE DISCHARGE LINE
SEPARATOR 10-V-1A
210 PSIG
THROTTLE VALVE
HIGH PRESSURE STEAM
LOW PRESSURE STEAM DISCHARGE LINE
SAMPLE PORT FOR STEAM
BEFORE ABATEMENT
LOW PRESSURE
STEAM
SAMPLE PORT FOR STEAM
AFTER ABATEMENT
SEPARATOR 10-V-1A1
20 PSIG
BRINE FLOW
TO KS-3
STEAM ROCK MUFFLER
TWO-PHASE FLOW FROM KS-8
NOT TO SCALE
PUNA GEOTHERMAL VENTURE
SEPARATOR AND ABATEMENT
SYSTEM, WELL PAD A
DATE 11/22/91
BY W. TEPLOW
FIGURE NO. 3-2

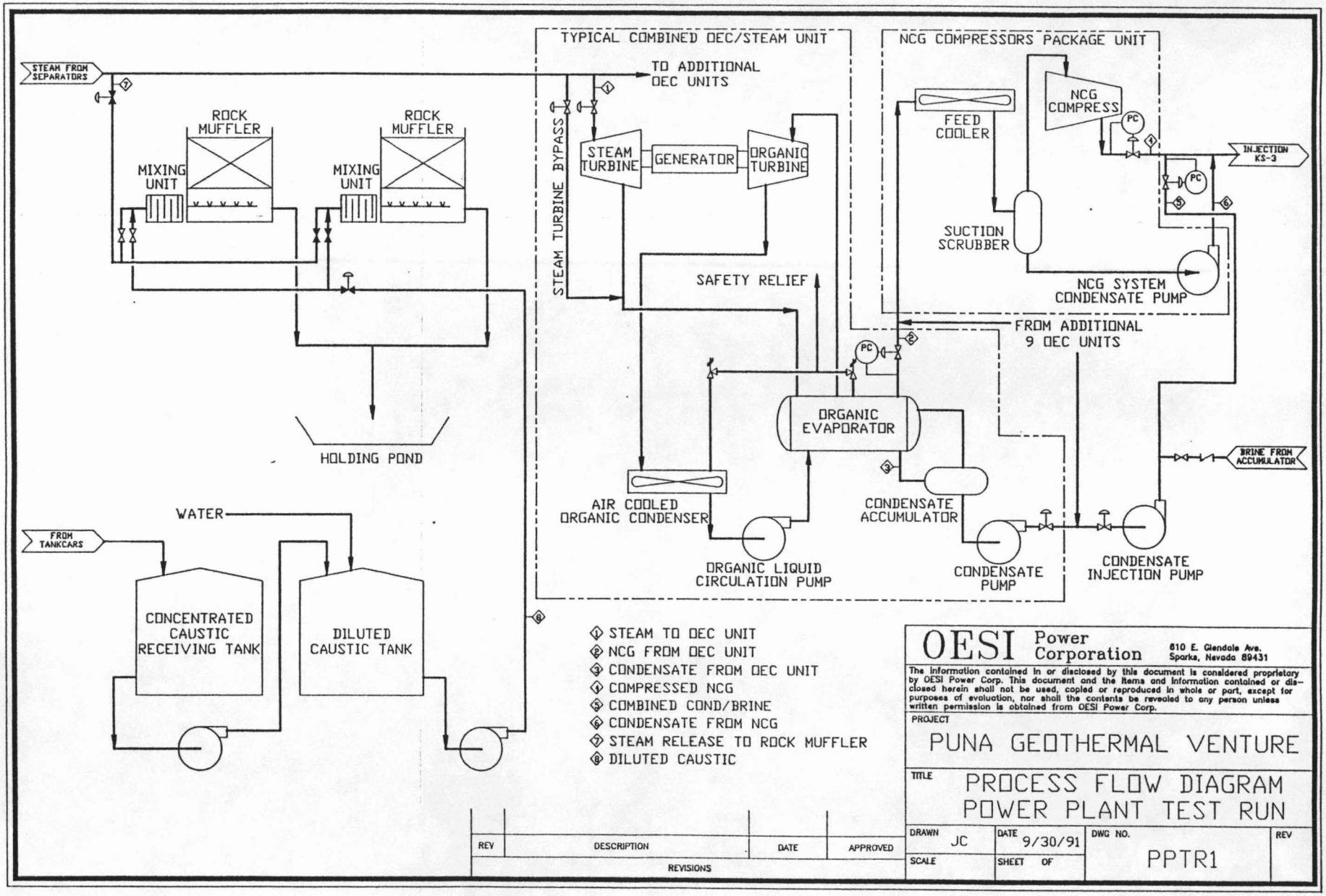

TYPICAL COMBINED OEC/STEAM UNIT
NCG COMPRESSORS PACKAGE UNIT
STEAM FROM SEPARATORS
TO ADDITIONAL OEC UNITS
ROCK MUFFLER
ROCK MUFFLER
MIXING UNIT
MIXING UNIT
STEAM TURBINE
GENERATOR
ORGANIC TURBINE
STEAM TURBINE BYPASS
FEED COOLER
NCG COMPRESS
INJECTION KS-3
SUCTION SCRUBBER
NCG SYSTEM CONDENSATE PUMP
SAFETY RELIEF
FROM ADDITIONAL 9 OEC UNITS
ORGANIC EVAPORATOR
BRINE FROM ACCUMULATOR
HOLDING POND
AIR COOLED ORGANIC CONDENSER
CONDENSATE ACCUMULATOR
ORGANIC LIQUID CIRCULATION PUMP
CONDENSATE PUMP
CONDENSATE INJECTION PUMP
WATER
FROM TANKCARS
CONCENTRATED CAUSTIC RECEIVING TANK
DILUTED CAUSTIC TANK
1 STEAM TO OEC UNIT
2 NCG FROM OEC UNIT
3 CONDENSATE FROM OEC UNIT
4 COMPRESSED NCG
5 COMBINED COND/BRINE
6 CONDENSATE FROM NCG
7 STEAM RELEASE TO ROCK MUFFLER
8 DILUTED CAUSTIC
OESI Power Corporation
810 E. Glendale Ave. Sparks, Nevada 89431
The information contained in or disclosed by this document is considered proprietary by OESI Power Corp. This document and the items and information contained or disclosed herein shall not be used, copied or reproduced in whole or part, except for purposes of evaluation, nor shall the contents be revealed to any person unless written permission is obtained from OESI Power Corp.
PROJECT
PUNA GEOTHERMAL VENTURE
TITLE
PROCESS FLOW DIAGRAM
POWER PLANT TEST RUN
REV DESCRIPTION DATE APPROVED
REVISIONS
DRAWN JC
DATE 9/30/91
DWG NO. PPTR1
REV
SCALE
SHEET OF

FIGURE 6 - 1

Schedule Name : KS-8 WELL TEST PROGRAM SCHEDULE
Responsible : William Teplow
As-of Date : 1-Dec-91 12:00pm Schedule File : C:\TL3\PGV\KS8TEST

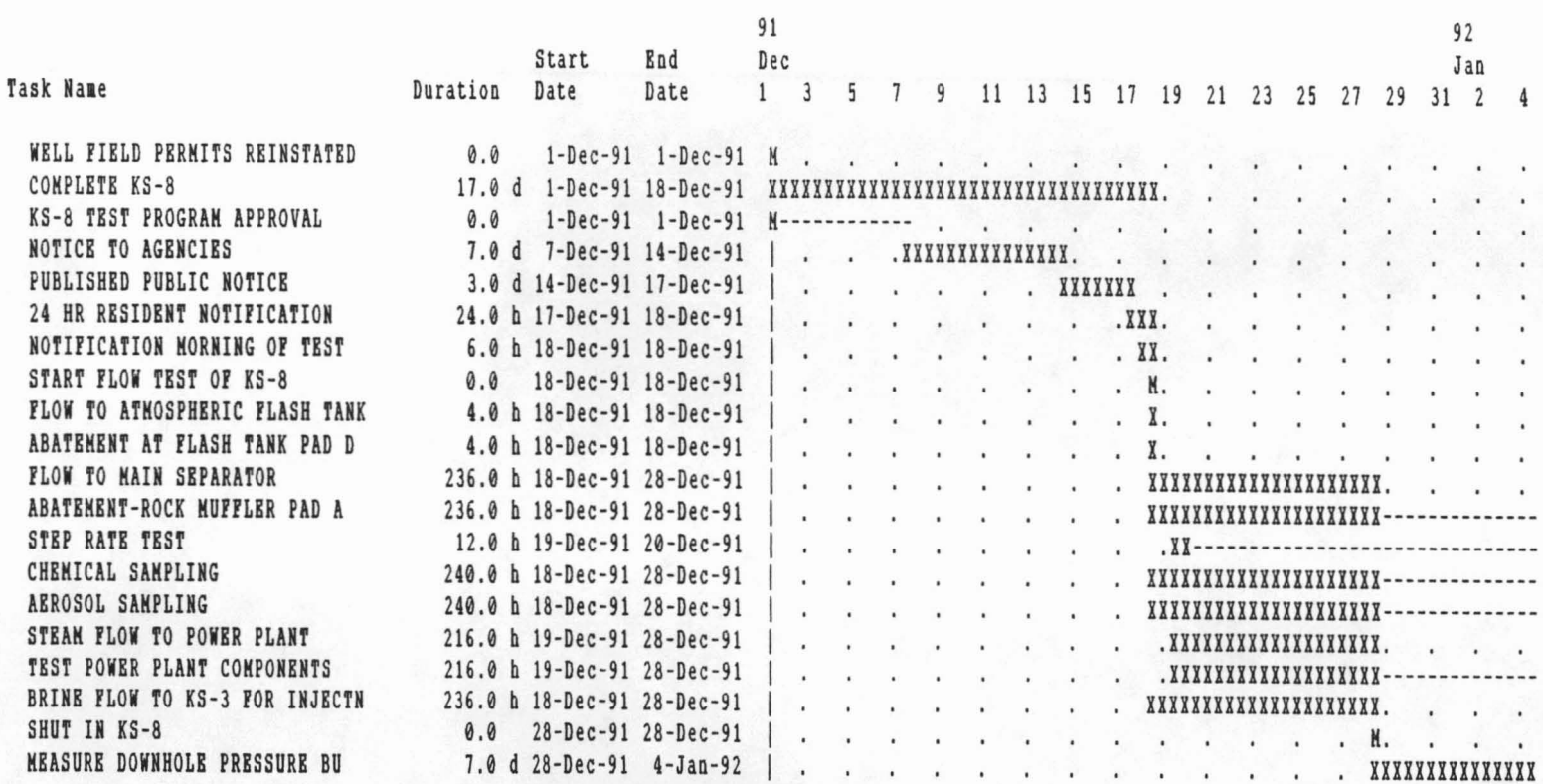


FIGURE 8-1

APPENDIX A

TOTAL SULFIDE DETERMINATION

USING THE SILVER ELECTRODE POTENTIOMETRIC METHOD

INTRODUCTION

This method of sulfide determination absorbs the H2S in the steam condensate into an aqueous sodium hydroxide solution. Silver Nitrate is then used as a titrant to precipitate the sulfide ion as Ag2S. The end point is readily determined by the sharp potential shift due to excess silver ion in the solution after all of the sulfide has precipitated. Silver ion concentration is measured using an ion specific electrode.

PROCEDURE

A. Sampling

1. Weigh dry gas wash bottle (A).
2. Add approximately 50 ml NaOH to completely submerge the gas bubbler tip and weigh the bottle again (B).
3. Collect approximately 80 ml condensate and weigh the bottle again (C).

B. Titration

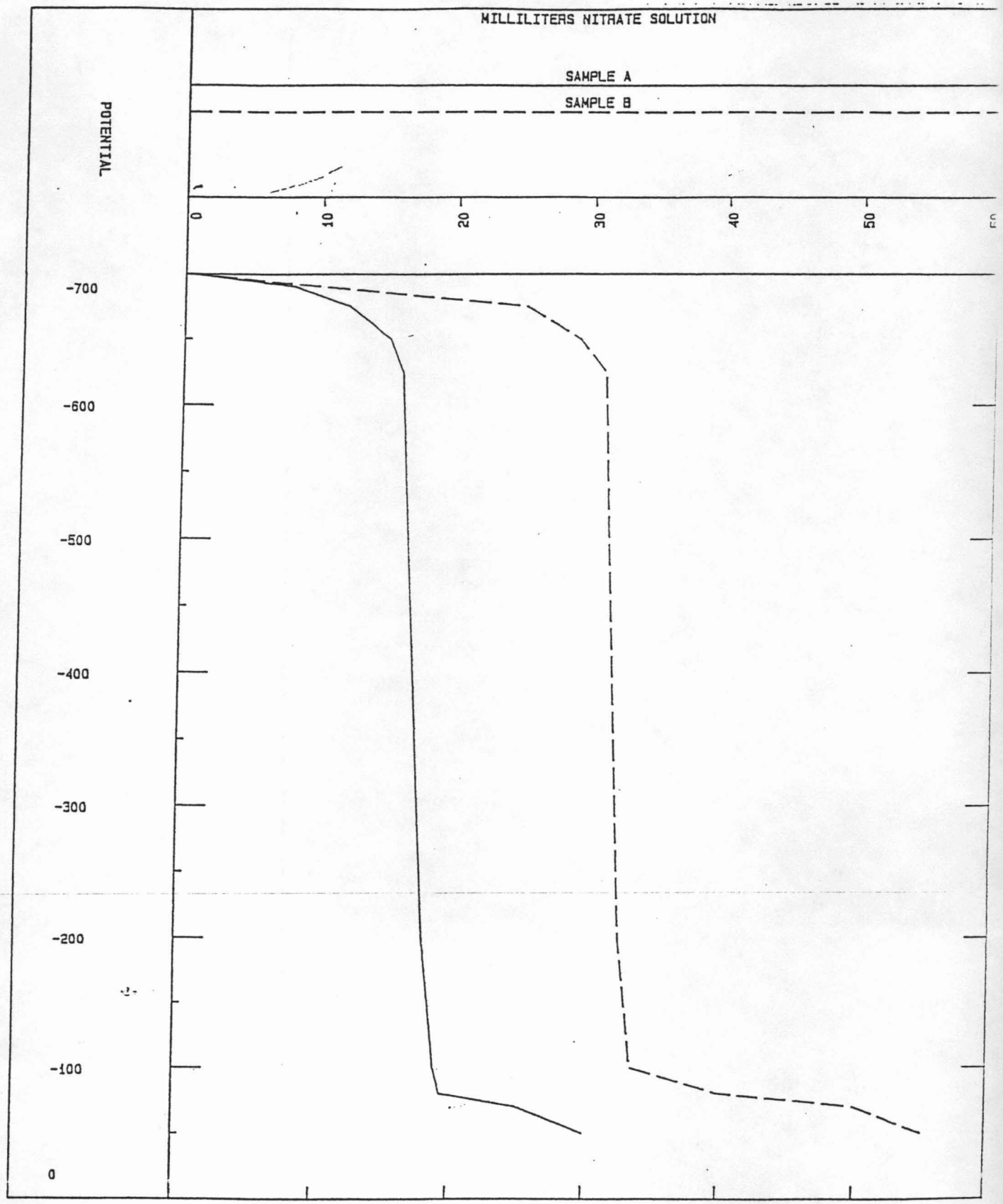
1. Weigh a dry 150 ml beaker.
2. Add approximately 50 ml of sample and weigh the beaker again.
3. Dilute the sample with approximately 50 ml distilled water.
4. Record the initial buret reading.
5. Titrate the sample using the AgNO3 solution until the end point is reached.

Since the endpoint to this titration is a sharp potential change (see figure 1) it will be necessary to add the AgNO3 slowly (about 1 ml/min) until the potential rises slightly. After this rise in potential, record the potential readings after adding each 0.1 ml of AgNO3. Continue adding the AgNO3 until there is a sharp rise in the potential; this is the end point. It is good practice to go beyond the end point to observe the flat part of the curve (see figure 1).

6. Record the final buret reading.

REAGENTS

NaOH	7%
AgNO3	10 g/liter


MILLILITERS NITRATE SOLUTION
SAMPLE A
SAMPLE B
POTENTIAL
0
10
20
30
40
50
-700
-600
-500
-400
-300
-200
-100
0

HYDROGEN SULFIDE DETERMINATION

OPERATOR _____ FLOW RATE _____

Well NO. _____ ORIFICE SIZE _____

DATE/TIME _____ WELL PRESSURE _____

TECHNICIAN _____ WELL TEMPERATURE _____

REMARKS _____

I. SAMPLING

(A) Weight of gas wash bottle _____

(B) Weight of bottle + NH_4OH _____

(C) Weight of bottle, NH_4OH + sample taken _____

II. TITRATION	Sample #1	Sample #2	Sample #3
Weight of beaker + sample			
Weight of beaker			
Weight of sample			
Final buret reading			
Initial buret reading			
Total $AgNO_3$ used			

III. POTENTIAL READINGS

Sample #1		Sample #2		Sample #3	
Buret Reading	Potential	Buret Reading	Potential	Buret Reading	Potential

DATA FOR H_2S DETERMINATION

CALCULATIONS:

$$H_2S\ (ppm_w) = \frac{\text{ml. } AgNO_3 \;\; \frac{10^{-3}\text{ g. } H_2S}{1\text{ ml. } AgNO_3} \;\; \frac{\text{Grams of Codensate + } NH_4OH}{\text{Grams of Condensate}} \;\; \frac{10^6\ ppm_w}{1}}{\text{Grams of Titrated Sample}}$$

$$H_2S\ (ppm_w) = \frac{(\text{Volume } AgNO_3 \quad (10^3) \quad \frac{(C-A)}{(C-B)}}{\text{Weight of Sample Titrated}}$$

SAMPLE #1 H_2S = _____ = _____ (ppm_w)

SAMPLE #2 H_2S = _____ = _____ (ppm_w)

SAMPLE #3 H_2S = _____ = _____ (ppm_w)

Average H_2S = _____ (ppm_w)

APPENDIX B

Summary of scale characterization analytic procedures

Characterization of Scale

The important elements in the complete characterization of scale are:

1. Determination of the rates of formation.
2. Scale mineralogy.
3. Scale chemistry.
4. Bulk density and porosity.

The above properties should always be established. Scaling rates are measured directly by determining the thickness of scale accumulation in various parts of a test facility. The rate of formation can be easily computed if total production corresponding to the measured scale thicknesses has been determined. Scale deposition in a wellbore can be established by the use of caliper logs run before and after a long-term flow period. Alternatively, a wireline scraper-bailer device can be used to collect samples of scale. The samples provide important information regarding both the formation rates and the identity of scale phases. Some scales are particularly adherent and hard such as the heavy metal sulfide and iron-rich siliceous scales characteristic of the hypersaline resources of southern California. It is difficult to completely remove these deposits from a wellbore using a scraper device. In these cases it is most useful to utilize data from calipers, if available, in conjunction with the recovered scale samples.

Mineralogy of scale deposits is obtained by the combination of x-ray diffraction analysis and optical petrographic techniques. It is sometimes useful to supplement these types of investigations with scanning electron microscopy analyses to better define microstructural attributes of the scales and as an aid in identifying fine-grained scale phases not identifiable by standard x-ray diffraction techniques. The use of EDAX-SEM capabilities is particularly good in identifying fines in a scale sample. The EDAX or energy

dispersive x-ray analysis yields qualitative microchemistry data for samples obtained in conjunction with an SEM analysis.

Chemistry of scale samples is more difficult to establish than the chemistry of a brine sample. The scale sample must be placed into solution prior to analysis. In the case of heavy metal sulfide scales containing large amounts of lead this is sometimes quite difficult as the lead and other heavy metals have a tendency to reprecipitate. Once a sample is in solution, analysis by ICP, AA or other techniques is straightforward. The preferred analytical scheme for scale samples is as follows:

1. Wash crushed samples repeatedly with distilled water to remove extraneous salts.

2. Dry the sample thoroughly in a vacuum oven and then obtain the sample weight.

3. Determine the acid solubility of the sample using hydrochloric acid. Ths is accomplished by treating a weighed amount of pulverized sample with concentrated hydrochloric acid and then determining the residual sample weight after filtration and drying. The insoluble residue is characterized subsequently.

4. Dissolution of samples for subsequent quantitative analysis is accomplished using concentrated hydrochloric acid in the case of acid soluble phases such as the carbonates. Heavy metal sulfide scales are dissolved in a hot mixture of hydrochloric, nitric, hydrofluoric and perchloric acids. Silica must be determined separately on a different sample split. Silica is determined after lithium metaborate fusion[72-73] of a sample and subsequent dissolution of the fusion cake with 3 percent nitric acid. The silica concentration is usually determined colorimetrically[3]. Analytical data are reported in units of ppm by weight (µg/gm).

In order to insure reliable results it is important to carefully homogenize samples prior to chemical analysis.

APPENDIX C

Summary of procedure for determining suspended solids and conducting membrane filtration tests

Suspended Solids - Determination of suspended solids or total filtratable residue is described in Standard Methods 208 D^3. Suspended solids obtained during the operation of in-line sampling trains is accomplished as follows:

1) Label a glass fiber or Millipore type HA or Nucleopore membrane filter with nominal pore size of 0.45 microns with a ballpoint pen. The label should be inscribed along the outer perimeter of the filter that will subsequently be covered by a mounting O-ring.

2) Predry the membrane filter at 103 to 105°C for 10-15 minutes (Millipore type HA filters should not be heated to temperatures in excess of about 60°C).

3) Allow the filter to cool in a desiccator.

4) Obtain the tare weight of the filter.

5) Mount the filter in a high pressure, in-line membrane filter holder (Millipore or equivalent). Be sure to place a fibrous prefilter pad beneath the membrane filter to enhance filtration rates.

6) Run the sampling train to waste for a minute or so to clean the lines.

7) Pass at least 100 ml of geothermal water through the filter. Measure the filtrate volume using a graduated cylinder.

8) Remove the filter assembly and take into laboratory.

9) Remove the top of the filter assembly and connect a vacuum system to the bottom drain line of the filter assembly. The filter can be held by a ringstand.

10) Repeatedly wash the filtered residue with 0.45 micron prefiltered deionized water. After each washing allow the water to drain completely.

11) Remove the filter from the filter assembly, after first breaking the vacuum, using membrane forceps. Transfer the filter to a watch glass. Remove and discard the prefilter pad.

12) Dry the filter in a vacuum oven at 103-105°C for 1 hour or longer depending upon the quantity of residue (Millipore type HA filters should not be heated to temperatures in excess of about 60°C).

13) Cool the filter and residue in a desiccator and then reweigh.

14) In the initial part of a study, reheat the residue several time and reweigh until a constant weight is achieved. Modify the procedure as necessary for subsequent analysis.

Required Calculations:

Weight of Filter + Residue = A (gm)
Weight of Filter = B (gm)

Volume of Filtrate = V (ml)

Total Suspended Solids (mg/l) = (A-B)x1,000/V

IV-18. Measuring Water Quality

The NACE standard (TM-01-73)[71] for measuring water quality is discussed by Patton[72]. The test consists of passing a known volume of injection water through a membrane filter under constant pressure and recording the flow rate and cumulative volume of water at intervals. The test is qualitative in nature and indicates the relative quality of injected water. Data is usually represented in the form of a graph of flow rate versus cumulative volume of water filter. The standard calls for the use of a 47 mm diameter, 0.45 μm membrane filter. The various configurations for carrying out a filter test are shown in Figures IV-25 to 27.

The basic test system configuration is shown in Figure IV-25. A reservoir is filled with injection water and pressurized with nitrogen. Fluid is then forced through a membrane filter mounted in an appropriate holder. A vent valve is used on he filter assembly to purge any trapped air before the filtration test is initiated. The filter assembly can also be purged using a vacuum pump as shown in Figure IV-26. For geothermal applications the system shown in Figure IV-27 is preferable since the properties and quantity of suspended solids could be significantly influenced by temperature, aeration and, to a lesser extent, pressure drop.

Temperature effects can be extremely significant in carrying out water quality measurements. Spent geothermal waters may commonly be saturated or supersaturated with respect to dissolved silica. Temperature decline would tend to promote additional silica precipitation. Calcium carbonate (calcite) has an inverse temperature solubility. Therefore, cooling a water or brine sample prior to and during testing may actually improve water quality with respect to the suppression of carbonate precipitation. Introduction of air

into a sample could induce precipitation of dissolved iron that could manifest itself as a significant reduction in apparent water quality. In general, the sampling and water quality measuring technique should be designed to minimize or eliminate changes in the basic injection water properties. In this regard, the ability to sample directly from a flowing reinjection stream and to perform the filtration test at or near in-situ temperature would be highly desirable.

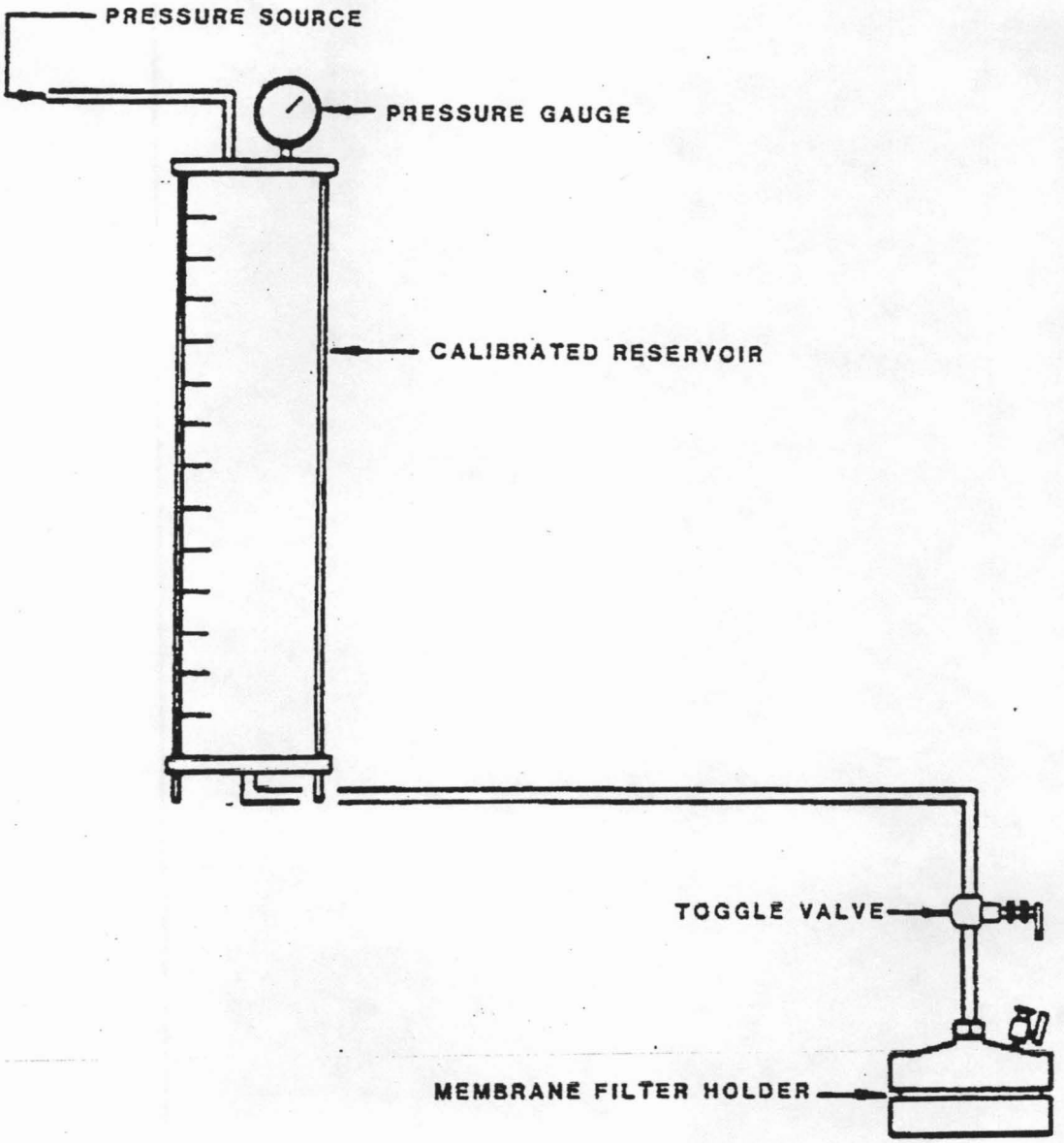


Figure IV-25. A two-stage apparatus with pressure gauge and regulator for repressuring and testing a sample collected in a reservoir rather than from the water handling system as in Figure IV-27. This apapratus is used primarily when the sample point cannot be readily adapted to on-stream application. To ensure that test conditions correspond with those of Figure IV-27, nitrogen gas is used to raise reservoir pressure to 20 psig.

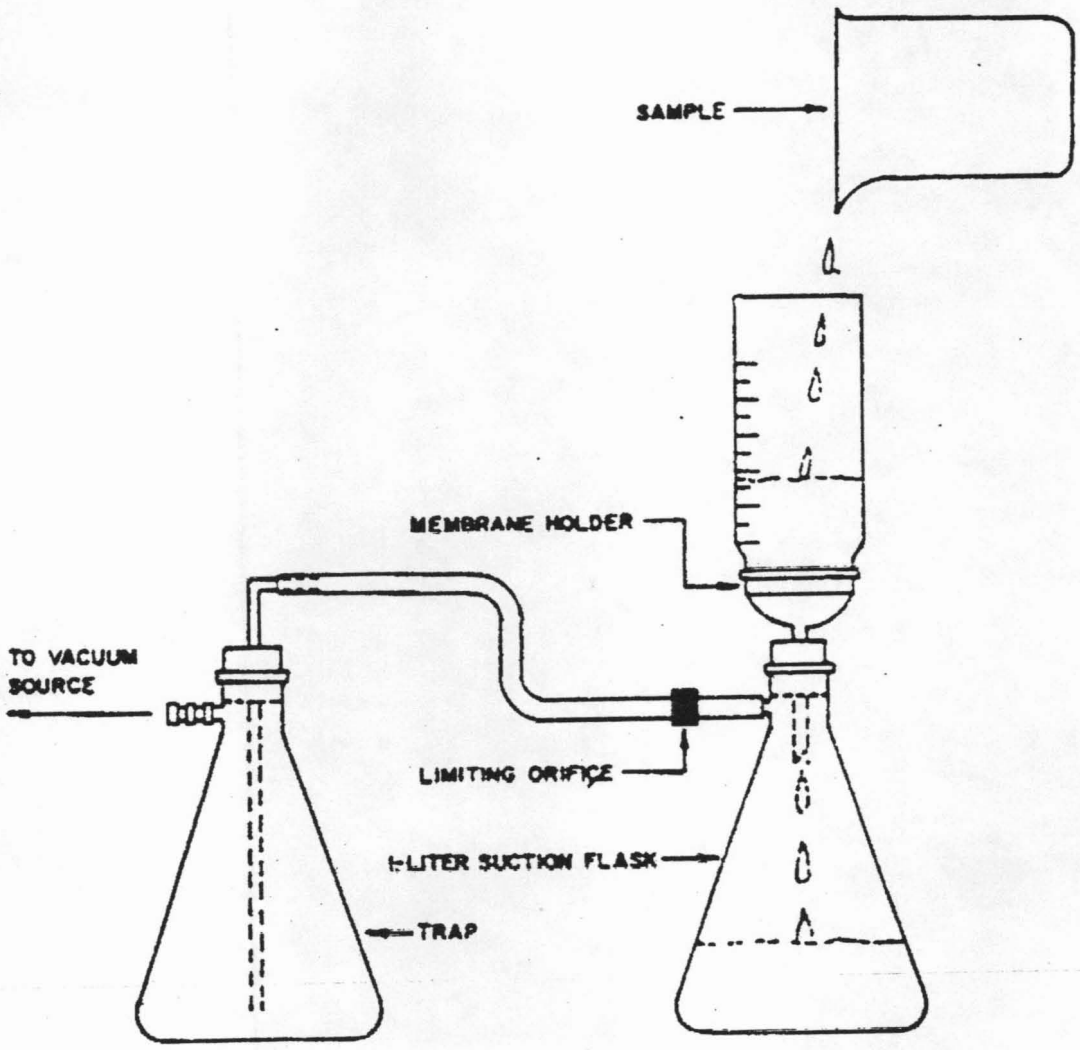


Figure IV-26. Apparatus for testing aged samples(secondary suspended solids) by vacuum filtration. The sample is poured into the cylinder over the holder, which contains a pre-weighed membrane filter. The vacuum source may be either a vacuum pump or water aspirator.

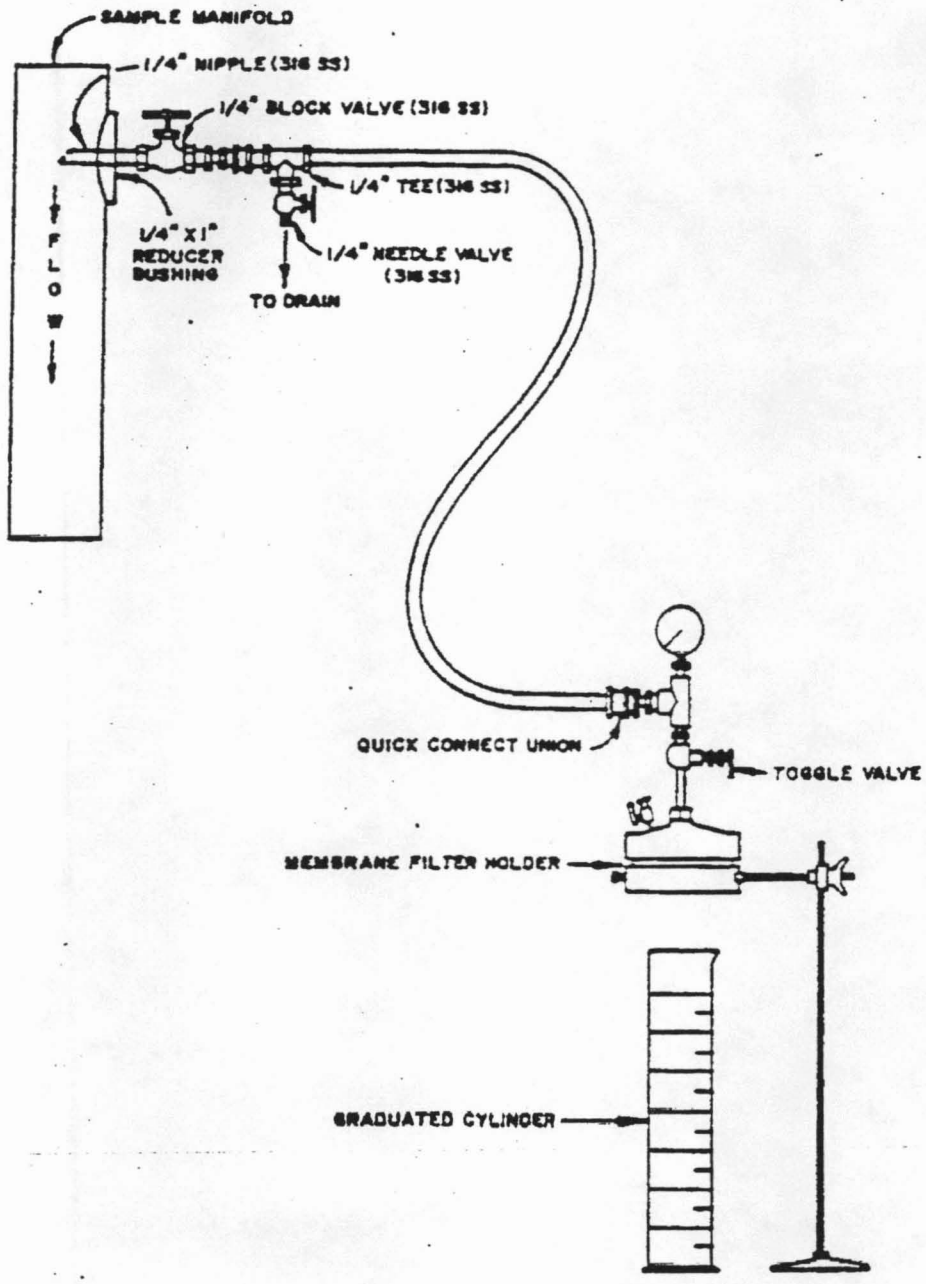


Figure IV-27. Membrane filter test apparatus showing a membrane filter holder connected to a water supply system. The ¼" block valve and needle valve shown near the top of Figure IV-27 control system pressure within prescribed limits. Just above the filter holder is a quick-opening type toggle valve to permit immediate, full-stream flow essential to timing accuracy.